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ABSTRACT

As part of an investigation of the effectiveness of a microcomputer-based laboratory (MBL) activity in developing students' graphing skills, this study was specifically designed to examine the differences between females and males in both performance on graphing tasks and on their attitudes to graphs and graph-based activities. Results based on a pretest of the participating secondary level students (N=93) revealed that about one-fifth of the students were seriously restricted in their ability to understand graphs by an inadequate graph schema. Females who had poor graph schemas appeared to have been constrained by their comparatively low ability, whereas the males were more likely to have been constrained by lack of interest. After controlling for differences in ability, some sex differences in performance on graphing tasks remained. Females had lower scores for items involving speed or velocity graphs, but not for graphs of miscellaneous graphs of less abstract properties such as distance. Discussed in this paper are two treatment groups that constructed distance and velocity graphs for one class period: (1) MBL group (N=18) used the microcomputer; (2) second (control) group (N=18) used paper and pencil. The females who participated in the MBL treatment gained significantly higher scores on a posttest of distance graphs, than the males did, while the reverse was true for velocity items. There were no sex differences for students in the control treatment. It was concluded that the MBL experience was effective in improving students' graphing skills. (ML)

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SEX DIFFERENCES RELATED TO GRAPHING SKILLS IN MICROCOMPUTER-BASED LABS

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Abstract

As part of an investigation of the effectiveness of a microcomputer-based laboratory (MBL) activity in developing students' graphing skills, this study examines the results for differences between males and females in both performance on graphing tasks and on their attitudes to graphs and graph-based activities. Female students were generally younger, and had lower measures of general ability and development than did males. They reported more difficulty and less enjoyment in working with graphs. After controlling for differences in ability, some sex differences in performance on graphing tasks remained. Females had lower scores for items involving speed or velocity graphs, but not for graphs of miscellaneous graphs of less abstract properties, such as distance.

Graphs constructed by students in a graph construction test revealed that about one-fifth of the students are seriously restricted in their ability to understand graphs by an inadequate graph schema. These students generally thought that graphs were less useful, than did the other students. Females who had poor graph schemas appear to have been constrained by their comparatively low ability, whereas the males were more likely to have been constrained by lack of interest.

For a single class period, students participated in either a series of MBL activities or a pencil-and-paper graph-construction exercise. Students in the MBL treatment gained significantly higher scores on a posttest of distance graphs, but not on a posttest of velocity graphs. This treatment effect was particularly strong for females. Among the students in the MBL treatment, after controlling for differences in ability and pretest performance, females showed more improvement for the distance items, whereas males showed more improvement for velocity items. However, male performance with the distance graphs was constrained by ceiling effects. The MBL experience was effective in improving females' graphing skills, compared with the control activity, but it is not possible to demonstrate who benefited more--males or females.

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Introduction

This study was part of an investigation of the effectiveness of a microcomputer-based laboratory (MBL) in developing students' graphing skills, specifically in developing the cognitive linkage between the occurrence of an event and the graphic representation of it. It examines the differences between males and females in both performance on graphing tasks and on their attitudes to graphs and graph-based activities.

Comprehending and interpreting graphs requires the ability to use abstract reasoning and on spatial visualization aptitude. It has long been recognized that gender differences affect spatial visualization skills. Males generally exhibit greater spatial skills than females, although these differences are frequently not apparent until adolescence (Maccoby & Jacklin, 1974). This has produced some vigorous debate about whether the differences are due to culture or heredity. Although there is considerable evidence from several areas of research that such differences are at least partly determined by genetic factors (Eliot & Fraley, 1976), there is also evidence that the gender gap has been declining (Hilton, 1985). Hilton attributes this to a convergence in the experiences of males and females.

MBLs display experimental data as graphs for the students to interpret. Research has demonstrated that experience with MBL activities improves students' ability to interpret graphs (Brasell, 1987; Mokros & Tinker, 1987; Linn et al., in press). It is important to examine activities, such as MBLs, that provide experience and practice with spatial tasks, such as graphing, for differential effects between the sexes.

Procedures

Students, mostly seniors, were from entire physics classes. The schools were nearly all rural, with small classes (maximum of 17 students in the class). Before the treatment, the students were tested for verbal ability, reasoning and development, and ability to interpret graphs. A content-specific (distance and velocity) pretest and a Likert-scale questionnaire to assess their attitudes to graphs were administered. Students also provided information on their ages and scores on standardized achievement tests.

Students were randomly allocated to four treatments, only two of which will be discussed in this paper for posttest results. The treatment period was only a single class period. Students in each treatment worked as a group. The MBL groups (18 students) worked with a series of inductive activities involving the representation of distance and velocity on Cartesian graphs. As they moved towards and away from the motion sensor, they used the microcomputer to collect experimental measurements of distance and time, to calculate velocity, and to display either distance graphs or velocity graphs on the screen. Worksheets guided them through a series of activities that included familiarization and observation, prediction, and application exercises. Students in the Pencil-and-Paper groups (18 students) constructed distance and velocity graphs of two complex movements. These movement events were the same as those being investigated by the MBL students.

On the day following the treatment, all students completed a content-specific posttest, a graph construction test, and a Likert-scale questionnaire to assess their attitudes to the activity. The graph construction test required students to construct a graph for representing raw data where time was not a significant variable. They were given a sheet of graph paper and a list of significant graph features.

Results

Of the 93 students who participated in the research, 44 were females. The numbers of males and females in each treatment group were similar. This in itself is encouraging, considering the historical bias against females in physical sciences. The females were younger, and had lower ability and lower development scores than males (Table 1). They reported that they had more difficulty constructing and interpreting graphs, and they enjoyed using them less than did males (Table 2). This was not just a difference in perception. After controlling for initial differences in ability, female students had significantly lower ($p \leq .05$) scores than males on the general graphing test, but only for the subset of items involving velocity-time speed-time graphs.

After the treatment activities, students in the MBL treatment performed significantly better than students in the Pencil-and-Paper groups for the distance items on the posttest, but there was no significant difference between treatments in their performances on velocity items (Table 3). This treatment effect was particularly strong for females. Brasell (1987) suggests that much of this improvement was with students' graphing skills, rather than with their understanding of the concepts of distance and velocity. After controlling for differences in covariates, there were significant sex differences on the posttest scores for students in the MBL treatment only. For the distance items, females scored significantly higher than did males, while the reverse was true for velocity items (Table 3). However, the performance of males on the distance-graph items was constrained by ceiling effects. There were no sex differences for students in the control treatment.

Females rated the MBL activity as significantly ($p \leq .10$) more difficult and confusing, and they said they enjoyed the activity less than did males. They volunteered as many comments on the bottom of their posttreatment questionnaire as did males. However, their comments were mainly that the activity was "fun" or were only peripherally related to the educational content of the treatment. In contrast, comments from males were related to learning, understanding, and being challenged.

Most of the students had considerable difficulty in the graph construction exercise. About one fifth of the 84 students who completed this test produced primitive, preCartesian graphs, in the sense that they used only one axis to represent two continuous variables. This is interpreted as meaning that these students had inadequate graph schemas. The data for students who had such problems were separated by sex, and compared with the rest of the students. Both males and females in this group reported that graphs were less useful than did the rest of the students. The twelve males in this group were similar to the average for all students on measures of SAT,

reasoning, and scores on the graph test. They tended to report a lower than average interest in graphs. In contrast, the six females were all low on each of these measures, and they indicated that they had more than average difficulty with graphs. Their inadequate graph schemas seem to reflect comparatively low general ability.

Conclusion

The general picture that emerges from these results is that females perceive graphs and graphing activities to be more difficult and less enjoyable than do males. Their graphing skills appear to be constrained by their lack of ability, whereas males are more likely to be constrained by lack of interest.

Both activities were predominantly grounded in graphing skills. The MBL activity facilitated the development of graphing skills compared to the Pencil-and-Paper control. Considering the very short treatment period (one class period), these results are encouraging. The strong treatment effect for females with distance-time graphs suggests that this type of experience may help females develop graphing skills. However, their comparative lack of improvement with velocity items suggests that they may need additional practice with graphs of properties that are neither too complex nor too abstract. It is not possible to determine from these results who benefited more--males or females. Rather than provide answers, these results define the questions that need to be addressed.

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Table 1. Sex differences on covariates and pretests.

Variable	Female (n=44)	Male (n=49)	sig.
Age (in months)	210	214	**
SAT	948	1030	**
DEV	23.6	25.2	**
Graph Test (%)	71	78	**
Miscellaneous (%)	74	78	
Speed (%)	68	79	**
Kinematics Test (%)	64	71	*
Distance (%)	84	84	
Velocity (%)	49	61	**

Significance: ** p $\leq$.05, * p $\leq$.10

Table 2. Sex differences in attitudes to graphs in science courses. Likert-scale items with 5 being the most positive response.

Item description	Females (n=44)	Males (n=49)	sig.
Graphs are useful	3.33	3.53	
Graphs are interesting	2.87	2.96	
Graphs are enjoyable	2.64	3.02	*
Not difficult to understand	3.20	3.55	**
Not difficult to construct	3.22	3.64	**
Used voluntarily	2.45	2.45	

Significance: ** p $\leq$.05, * p $\leq$.10

Table 3. Sex differences on kinematics posttest (%), with significance levels after controlling for individual differences on ability and pretest scores.

	Treatment						Treatment sig.
	Standard MBL			Pencil-and-Paper			
	Female (n=9)	Male (n=9)	Sex sig.	Female (n=8)	Male (n=10)	Sex sig.	
Distance	93			55			**
8 items		89	**		72	ns	ns
Velocity	58			60			ns
16 items		78	**		62	ns	ns
Total	70			58			**
24 items		82	ns		66	ns	ns